GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 2/4/81

Project Title: Industrial Hygiene Monitoring for the Iowa Power & Light Company

Project No: A-2851

Project Director: Mr. W.C. Howard

Sponsor: Iowa Power & Light Company

Agreement Period: From 2/2/81 Until 4/1/81 (Perf. & Rpts.)

Type Agreement: Research Agreement No. A-2851

Amount: $7,500

Reports Required: Final (Due 4/1/81)
Note: No Deliverable Schedule issued

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Defense Priority Rating: N/A

Assigned to: EDL/BDD (XXXXX/Laboratory)

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GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 5/15/81

Project Title: Industrial Hygiene Monitoring for the Iowa Power and Light Company

Project No: A-2851

Project Director: W. C. Howard

Sponsor: Iowa Power and Light Company

Effective Termination Date: 4/1/81

Clearance of Accounting Charges: 4/1/81

Grant/Contract Closeout Actions Remaining:

- x Final Invoice and Closing Documents
- _ Final Fiscal Report
- _ Final Report of Inventions
- _ Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- _ Other _____

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CA—4 (1/79)

A-2851
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INDUSTRIAL HYGIENE SURVEY
for
Iowa Power and Light Company
Des Moines, Iowa

March 27, 1981

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I. INTRODUCTION

Iowa Power and Light Company retained Georgia Tech Research Institute (GTRI) to conduct a limited industrial hygiene survey of selected company facilities. The purpose of the survey was twofold: (1) to monitor specific areas and operations for employee exposure to a variety of potentially harmful chemical and physical agents and (2) to provide some in-service training in basic industrial hygiene practices for several technicians employed by Iowa Power and Light.

The monitoring part of the survey included the collection of area samples for asbestos, PCB's, cyclohexylamine, morpholine, hydrazine, sulfur dioxide, and carbon monoxide. Samples were also collected to measure personal exposure to total nuisance dust, respirable coal dust, silica, asbestos, acetone, perchloroethylene and naphtha.

The survey was conducted from February 2 thru February 6, 1981, and included the Des Moines Power Station (DPS), the Council Bluffs Power Station (CBPS), the Delaware Service Center, River Hills substation and the Walnut Street offices. The field survey work was done by Kenneth A. Smith of G.T.R.I. with assistance from Mr. Lynn Wallis, Tom Shifflet, Robin Fortney, at the Des Moines Power Station, and David De Roos at the Council Bluffs Power Station.

This report includes conclusions and recommendations based upon the laboratory analysis of collected samples and personal observations of work practices and discussions with a variety of employees of Iowa Power and Light Company. Appendix A contains a discussion of each sampling and analytical method; Appendix B summarizes the sampling results; Appendix C contains appropriate regulations governing contaminants identified in the survey; Appendix D reviews the toxicological effects of these contaminants and Appendix E includes a list of basic reference materials for each of the industrial hygiene technicians.

II. CONCLUSIONS

A. Noise

1. Noise Dosimetry readings at the Council Bluffs Power Station did not indicate any individual exposure in excess of the current IOSH PEL of 90 dB(A) based on an 8-hour TWA. Three of fourteen individual dosimeter readings at the Des Moines Power Station indicated exposures above 90 dB(A).

2. Hearing conservation programs have been instituted at both power stations but based on observations made during this survey, the rules regarding the wearing of hearing protection appear to be better enforced at Des Moines.

3. At Council Bluffs, three of the five dosimeter measured personal exposures to noise observed during this survey were between 85 and 90 dB(A). This observation is in agreement with the October 1980 study by Clayton Environmental Consultants where 40% of the observed exposures fell into this area. With the passage of the amendment to section 1910.95 of the federal noise standard scheduled to take effect April 15, 1981, these results take on added significance and will necessitate a more rigid enforcement of the hearing protection requirements at Council Bluffs.

B. Coal Dust and Crystalline Silica

1. Total Dust

None of the eight personal samples collected for total dust exposures exceeded the IOSH PEL of 15 mg/m^3 for an 8-hour TWA for nuisance particulates. Likewise, for six of those eight samples (which contained more than 1% silica) the calculated total dust exposure in each case was below the PEL for dusts containing silica.

2. Respirable Coal Dust

Fourteen samples were analyzed to determine employee exposure to respirable coal dust. Because the silica content of the coal was less than 5%; the IOSH PEL for total respirable coal dust of 2.4 mg/m^3 based on an 8-hour TWA is the applicable standard for determining compliance. All samples analyzed (five at DPS and nine at CBPS) showed an airborne concentration of respirable coal dust less than the IOSH PEL.

C. Asbestos

1. Analysis of bulk samples of insulation and finish materials from a variety of surfaces within the Walnut Street offices indicate the presence of one or more asbestos forms. In general, the physical condition of these materials is such that very little asbestos is becoming airborne. Under the best of circumstances however, with the passage of time and the inevitable deterioration in the integrity of the exterior surface, some of this material will become airborne. Based on the analysis of the air samples taken at a number of points in this building it is clear that the current airborne levels do not represent an excessive exposure based on any present standards or any currently recommended standards.

2. Samples for airborne asbestos were taken at both DPS and CBPS during insulation removal operations in the stations. Although none of the samples indicated an over-exposure

based on the IOSH PEL, there was a significant difference in the relatively high levels seen at DPS compared to those at CBPS.

D. Polychlorinated Biphenyls

All samples taken to measure airborne concentrations of Polychlorinated biphenyls (PCB's) at River Hills Substation and Delaware Service Center were well below the IOSH PEL. Wipe samples of surfaces previously cleaned after PCB leakage did show some remaining contamination.

E. Water Treatment Chemicals

Samples taken to monitor airborne levels of hydrazine, morpholine, and/or cyclohexylamine did not indicate airborne contamination in the vicinity of either the dispensing areas or the mixing tanks at the point of application.

F. Solvents

Samples taken to measure personal exposure to Acetone, Perchloroethylene and Petroleum Naphtha in the Print Shop at Walnut Street did not indicate an over-exposure to any of these solvents.

G. Miscellaneous

Direct reading measurements taken for Sulfur dioxide (SO_2), Carbon monoxide (CO), or Mercury (Hg) did not represent significant exposure conditions at the time of this survey.

III. DISCUSSION AND RECOMMENDATIONS

A. Noise

Although there are well defined areas at both power stations where continuous noise levels are in excess of 90 dB(A) (see Clayton Environmental Consultants Reports 1010-879-ATL, Nov. 12, 1979) only three dosimeter readings indicated an employee exposure above the current IOSH PEL. These three exposures, two maintenance workers and one equipment operator, all worked at the Des Moines Power Station. Hearing protection was worn by these employees.

While none of the current noise dosimetry readings at Council Bluffs Power Station were above 90 dB(A) three readings fall between 85 and 90 dB(A). The probability is that most power station employees would experience average daily noise exposures above 85 dB(A) but less than 90 dB(A). This fact will

take on added significance with the current amendment to section 1910.95 assuming it will go into affect on April 15, 1981, as scheduled and as it is now written. Among other provisions this amendment will require monitoring of most employee groups working in the power station, audiometric testing for each employee exposed above an 8-hour TWA of 85 dB(A), training for all employees so exposed, and specific new requirements concerning methodology and equipment for noise measurement. Included in this last requirement is the use of a noise dosimeter with the capability of recording all noise impulses as low as 80 dB(A).

B. Coal Dust and Crystalline Silica

Twenty-one personal samples from employees at DPS and CBPS were taken to evaluate employee exposure to coal dust and crystalline silica. Eight of these samples (five at DPS and three at CBPS) measured employee exposure to total dust. None of these samples exceeded the IOSH PEL for total nuisance dust or the allowable limit for silica exposure.

Fourteen personal samples from employees at DPS (five samples) and CBPS (nine samples) for respirable dust were also collected and analyzed for crystalline silica content. None of these samples exceeded the IOSH PEL of 2.4 mg/m^3 for respirable coal dust.

Based on these data, and previous sampling data from the October, 1980 survey, employee exposure to coal dust does not appear to present a problem at this time.

C. Asbestos

Because of its unique thermal degradation characteristics and its long term stability, asbestos is a material so widely used in building construction that we will have to live with it for long periods of time or face financially debilitating removal costs. Iowa Power and Light Company is not alone in this dilemma but that fact provides little in the way of help in deciding how to deal with the presence of asbestos in the work place. Public statements by acknowledged authorities who maintain steadfastly that there is no safe level of exposure tend to fly in the face of the experience we have faced with other environmental hazards. In the present atmosphere most authorities tend to rely heavily on existing or proposed standards in evaluating a specific exposure problem. In the case of asbestos it is important to look at the only legal standard for airborne exposure which is 2.0 fibers (longer than 5 microns) per cubic centimeter of air.

With respect to the low airborne levels found in the samples at the Walnut Street office building, it should be recognized that this situation will continue to be something requiring attention. Any repair work done in and above suspended ceilings should be evaluated in terms of potential worker exposure and airborne monitoring would be advisable for those employees performing such work. The results of such monitoring may affect decisions on removal or perhaps the application of sealant in cases where the asbestos containing material is loosely bonded. Sealing with a penetrating polymer applied to the surface would be considerably less expensive than removal and may be particularly applicable for the ceiling of the Assembly Hall on the first floor if and/or when deterioration of this ceiling would pose a hazard.

Repair of pipe insulation in the power plants will continue to be a difficult problem because of the need to remove old asbestos insulation. The lower airborne levels observed at the Council Bluffs insulation removal job are primarily a reflection of the fact that the worker at Council Bluffs was able to completely saturate the material with water before he removed it. At Des Moines the workers began the removal procedure before the insulation was thoroughly saturated which resulted in a visible cloud of dust being released.

In both cases there was a demonstrated need for more thorough preparation and planning of such jobs before they are actually begun. Where possible, asbestos removal areas need to be sealed off by curtains of polyethylene plastic and the floor covered with a plastic sheet, no less than 6 mil in thickness. In the case of pipe lagging removal, the impervious outer covering needs to be cut open and the inner material sprayed thoroughly, preferably with a fine mist of water and a surfactant from a pressurized sprayer. This should minimize the total volume of water and reduce the problems of clean-up.

Personal protective clothing used during the above removal jobs was adequate and the employees involved appeared to be conscientious in using disposable clothing.

While it is recognized that the single-use type of air purifying respirator in use at the power stations carries an MSHA/NIOSH approval and certification for use against fibrosis producing dusts including asbestos, the companies attention is directed to the December 1980, issue of the American Industrial Hygiene Journal which carries a reprint of a letter from NIOSH to all respirator manufacturers. Essentially NIOSH has taken the position that the use of such respirators as protection against a known carcinogen is questionable despite the issued approval number.

D. Polychlorinated Biphenyls (PCB's)

Four area samples for measuring airborne concentrations of polychlorinated biophenyls were collected (three at River Hills and one at the storage facility at Delaware Service Center). Sample results indicate airborne concentrations well below the IOSH PEL of 1 mg/m^3 for chlorodiphenyl (42% chlorine) and 0.5 mg/m^3 for chlorodiphenyl (54% chlorine).

One of two wipe samples taken at River Hills indicates a need for more thorough clean-up of leakage or spills at transformers in the River Hills substation. Workers involved in such clean-up should be properly protected against the possibility of absorption of PCB residue through the skin.

E. Water Treatment Chemicals

All samples collected for the evaluation of airborne exposure to hydrazine, cyclohexylamine and morpholine were area samples taken in close proximity to the drum containers, either in the dispensing area or at the point of application at the mix tanks. All sample results indicated airborne concentrations at a very low level, well below the IOSH PEL's for these compounds.

Perhaps more important than these results are the work procedures established at the Des Moines Power Station for hand carrying measured quantities of hydrazine and/or cyclohexylamine from the dispensing area to the mixing tanks. A closed transfer system similar to that established at Council Bluffs Power Station would be one way to minimize this hazard.

F. Solvents

Based on the sample results, it would appear that employee exposure to various solvents in the print shop is well controlled. Exposure to perchloroethylene should be held to an absolute minimum pending the outcome of research presently underway to evaluate its potential human carcinogenicity. Of particular importance is the provision of polyethylene or neoprene gloves for use when applying perchloroethylene containing solvents to print rolls or equipment as a cleaning agent.

G. Mercury

During the course of the survey at DPS there were several instances where areas contaminated by mercury spills were not thoroughly cleaned. In most instances these spills were in areas behind instrument panels and were the result of maintenance work on mercury containing instruments and/or

controls. Based on the visible dust and dirt at these locations and the lack of response from the mercury sniffer used during the survey, it would appear that these spills are not recent ones. In any event such contamination should be carefully removed. Vacuum cleaners used for this purpose should be equipped with mercury vapor absorbing filters to prevent further dispersal of vapors. Perhaps a better technique for small spills such as these is to utilize one of the kits currently on the market for the clean up of mercury spills.

H. Technician Training

The development of an in-house capability to perform routine industrial hygiene monitoring has been initiated at DPS and CBPS. Laboratory technicians at the power stations were very helpful in the conduct of this survey and appeared to have the interest and ability to perform the monitoring function. Every effort should be made to upgrade and standardize sampling procedures performed by power station personnel. In that regard it is recommended that several publications be acquired as reference literature for their use. These publications are included in Appendix E.

This report prepared by:

Kenneth A. Smith
Industrial Hygienist

This report approved by:

James L. Burson, C.I.H.
Industrial Hygienist
Project Director

APPENDIX A

Sampling and Analytical Methods

ASBESTOS

Samples for the determination of airborne asbestos fibers were collected by drawing air at measured flowrates through open-face cassettes containing 37-millimeter diameter cellulose ester membrane filters (Millipore, Type AA) using battery-powered, portable pumps. After collection of each sample the cassette was covered and sealed immediately for transport to the laboratory.

Each sample was analyzed subsequently for asbestos fibers using the microscopic technique currently specified by the National Institute for Occupational Safety and Health (NIOSH). Briefly, the technique consisted of the following steps: a wedge-shaped sector of each filter was cut carefully from the sample and mounted on a standard microscope slide, using a high-viscosity solution of membrane filter material in a 1:1 mixture of diethyl oxalate and dimethyl phthalate to render the filter transparent. Asbestos fibers, defined as particules having aspect rations (apparent length to width) of three or greater, which were observable on the surface of the filter were counted using a binocular microscope equipped with 10X eyepieces and a 40X objective with phase contrast illumination. Porton reticle fields, selected at random on the sample, were examined and fibers greater than five micrometers in length were counted until either of two conditions was satisfied:

1. A minimum of 100 fibers was counted in 20 or more fields.

2. A minimum of 100 fields was examined.

Results of the microscopic analyses were used in conjunction with field sampling data (measured flowrates and durations of sampling) to calculate the concentrations of airborne asbestos fibers corresponding to each sample in units of fibers greater than five micrometers in length per cubic centimeter of air (fibers > 5 μm per cc).

ANALYSIS OF BULK SAMPLES FOR ASBESTOS BY X-RAY DIFFRACTOMETRY

Sample material is ground in ball mill for ten minutes. A precisely weighed portion of the ground sample (approximately 100 mg) is weighed and suspended in a solution of 0.05% Triton X-100 to obtain a suspension of approximately 100 mg sample per liter.

Fifty ml of the suspension is filtered by vacuum through a 25 mm diameter Nucleport (polycarbonate membrane) filter (0.4 μm port size).

The filter sample is then analyzed by X-ray diffraction employing a copper target emitting $K\alpha$ radiation of wave-length 1.542A. (This is a mean value calculated using the equation $K\alpha = 1/3 (K\alpha_2 + K\alpha_1)$ where $K\alpha_1 = 1.540$ and $K\alpha_2 = 1.544$. A scintillation detector monitors the intensity of the diffracted energy as the samples are scanned in the range $2\theta = 7.5$ to 14°. (where θ is the angle of incidence of the radiation in the Bragg equation: $n\lambda = 2d\sin\theta$) If diffraction peaks are detected corresponding to the primary diffraction peaks of the asbestos forms (e.g., the primary diffraction peak of chrysotile at $2\theta = 12.0$ and the primary peak of amosite at $2\theta = 10.5$), or if interferences are present in this region, the sample is scanned from $2\theta = 23.0$ to 36.0 and any peaks present are compared to the secondary, tertiary and lesser diffraction peaks of the asbestos forms. The quantity of asbestos present in each sample is determined by comparison of the heights of the appropriate diffraction peaks on the sample diffraction scans with the heights of the corresponding peaks on the diffraction scans of standards prepared in like manner.

CARBON MONOXIDE

Sampling for carbon monoxide (CO) was conducted by using the following two techniques.

Short-term area sampling (direct reading instantaneous) was performed either by drawing measured volumes of air through a length of stain detector tube via a hand-operated sampling pump, or by a direct-reading meter.

In the detector tube system, the CO indication is based upon the reduction of potassium palladosulfite impregnated silica gel giving a color change of yellow to brown in the presence of CO. The length of stain of the detector chemical is proportional to the CO concentration (in ppm) and must be matched to a chart corresponding to the number of pump strokes employed (1 full stroke = 100 cc) on the instruction sheet which accompanies the tubes.

The basic principle of operation of the direct reading meter involves drawing air (pre-cleansed to remove interferences) through an electrochemical sensor cell at a nominal flowrate of 700 cc/minute. The sensor cell is composed of a catalytically active sensing electrode (platinum), a counter electrode, a reference electrode and an aqueous sulfuric acid solution as the electrolyte. In the direct reading meter, the electro-chemical process is carried out at a potential-controlled electrode. The current measured upon introduction of CO to the sensor cell is the result of the electro-oxidation of CO to carbon dioxide (CO_2) and is proportional to the partial pressure of CO in the sampled air.

CYCLOHEXYLAMINE

A calibrated sampling pump was used to collect a known volume of air (at an approximate flowrate of 0.1 l/min). The collection medium used was a silica gel tube (7 cm long by 4-mm I.D.) containing two sections of 20/40 mesh silica gel separated by a 2-mm portion of methane foam. The absorbing section contains approximately 150 mg of silica gel, and the backup section contains approximately 75 mg.

The analyte was desorbed from the silica gel with 0.5 M sulfuric acid, and an aliquot of the desorbed sample was neutralized with 1.2 M sodium hydroxide. The sample was separated and analyzed using a gas chromatograph with a nitrogen-phosphorous detector.

Areas beneath the resultant peaks are then integrated to obtain a value of the analyte present (in micrograms) in the sample. From this value and the total air volume sampled the concentration of cyclohexylamine may be calculated as mg/m3. Desorption efficiencies and blanks are run in parallel with the samples utilizing spiked and blank silica gel tubes, respectively. The sample values are then adjusted accordingly.

HYDRAZINE

A calibrated personal sampling pump was used to draw a known volume of air through a filtered glass bubbler containing 10 milliliters of collection medium. The flowrate used was approximately 1 liter per minute with a greater than 100 liter sample as a minimum volume. The collection medium used was 0.1M hydrochloric acid. After sampling was completed the solution was transferred to a 30 ml sample vial rinsing the bubble with 0.1 M hydrochloric acid.

The solution was then made alkaline and reacted with p-dimethylaminobanzaldehyde solution to form a colored complex. The amount of complex is determined with a spectrophotometer to give a quantitative measure of hydrazine. A value was determined (in micrograms) and the airborne concentration calculated and subsequently reported in mg/m3. Adjustments in this value were made (if necessary) by subtracting the blank value run in parallel with the analysis.

MORPHOLINE

A calibrated sampling pump was used to collect a known volume of air (at an approximate flowrate of 0.1 l/min). The collection medium used was a silica gel tube (7 cm long by 4-mm I.D.) containing two sections of 20/40 mesh silica gel separated by a 2-mm portion of methane foam. The absorbing section contains approximately 150 mg of silica gel, and the backup section contains approximately 75 mg.

The analyte was desorbed from the silica gel with 0.5 M sulfuric acid, and an aliquot of the desorbed sample was neutralized with 1.2 M sodium hydroxide. The sample was separated and analyzed using a gas chromatograph with a nitrogen-phosphorous detector.

Areas beneath the resultant peaks are then integrated to obtain a value of the analyte present (in micrograms) in the sample. From this value and the total air volume sampled the concentration of morpholine may be calculated as mg/m3. Desorption efficiencies and blanks are run in parallel with the samples utilizing spiked and blank silica gel tubes, respectively. The sample values are then adjusted accordingly.

NOISE

Sound pressure level measurements were taken with Type II Sound Level Meters manufactured in accordance with the American National Standards Institute (ANSI) S1.4 - 1971 "Specifications for Sound Level Meters". General area and operator station sound pressure levels were measured on the "A-weighted slow response" integrating network, which approximates the response of the normal human ear to sound, at the workers' ear level as specified in ANSI S1.13 - 1971 "Methods for the Measurement of Sound Pressure Levels".

When industrial noise is transient and variable, a reasonably accurate determination of compliance with existing standards can be made with an Audio Dosimeter which automatically time-weights and integrates the various exposure conditions. Readings from this device are reported as a percentage of the current allowable exposure limit and have been corrected to reflect eight-hour, time-weighted averages. A representative number of sound level readings are taken while the dosimeters are being used in order to verify the dosimetry percentage readings.

The first step in the engineering control of industrial noise requires a comprehensive characterization of all major sources of noise, including an analysis of the individual sound pressure levels in the 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16000 using approved Octave Band Analyzers.

All noise instruments were calibrated in accordance with the manufacturers' recommendations prior to and immediately following use. Sound level meters were calibrated using the appropriate Sound Level Calibrators.

NOISE DOSIMETRY

Noise dosimetry studies of employee noise exposures were made using DuPont, Model D-376, Audio Dosimeters, set for a 90 dBA cutoff.

Sound levels reaching the employee were detected by a non-directional ceramic microphone worn on the shirt collar. This input is attenuated using the "A" weighting scale described in the American National Standards Institute S1.4-1971 "Type 2 Specification". If the microphone picks up any continuous sound over 115 dBA, it is recorded and stored for later inspection.

Next noise below the cutoff level, 90 dBA, is removed on a continuous basis. The ratios of actual exposure to established limits at every sound level between 90 and 115 dBA are calculated and integrated with time to give the actual exposure during the workday as a percentage of that permitted by the regulations.

Data storage is accomplished by means of an electroplating reaction that occurs within an integrating memory cell. The information is stored in the cell until it is retreived in a DuPont, Model R-225 readout instrument by reversing the electroplating reaction. The memory cell is automatically cleaned for reuse as the exposure information is retrieved.

Prior to use, the Audio Dosimeter battery is checked with an internal battery check and calibrated at two sound levels with a DuPont, Model C-114, calibrator.

ORGANIC VAPORS

Samples were collected by using battery-powered, portable pumps to draw air at measured flowrates through:

1. Charcoal Sample Collection Tubes, containing 450-milligram (front) and 150-milligram (back) sections of activiated charcoal, or

2. Charcoal Tubes containing 100-milligram (front) and 50-milligram (back) sections of activated charcoal.

Immediately after sampling, the ends of tubes were sealed with polyethylene caps for transport to the laboratory, where they were refrigerated until analysis.

In the laboratory, front and back sections of each tube were desorbed separately in appropriate volumes of carbon disulfide, and aliquots of the resultant solutions injected into a gas chromatograph. Quantities of each analyte present were determined by comparison of areas under the sample chromatogram peaks with areas under chromatogram peaks for standards prepared in carbon disulfide. Analytical results, which include any necessary corrections for parallel blank and recovery determinations, were used in conjunction with sampling data (volume of air sampled) to calculate the concentrations of airborne analytes represented by each sample, expressed in parts analyte per million parts of air, by volume (ppm).

POLYCHLORINATED BIPHENYLS

A measured volume of air is drawn through a small sorbent tube containing deactivated florisil using a battery-operated portable pump at a nominal flowrate of 1 liter per minute. Subsequent to sample collection the ends of the sorbent tube are sealed and immediately shipped to the laboratory where they are refrigerated until analysis.

Each sample is desorbed using hexane and analyzed by gas chromatography with electron capture detection. The concentration of PCB relative to a PCB standard is determined from a standard curve. The concentration of polychlorinated biphenyls present in the sample is calculated, after corrections (if necessary) for blanks and recovery samples run in parallel, and reported as total micrograms per sample.

RESPIRABLE DUST AND FREE SILICA

Samples to be analyzed for "respirable" dust and crystalline free silica were collected by using battery-powered, portable pumps to draw air at a nominal flowrate of 1.7 liters per minute through 37-millimeter diameter polycarbonate membrane filters, 0.8 micrometer pore size contained in cassettes preceded by 10-millimeter nylon cyclone particle size selectors.

The mass of particulate matter collected on each filter was determined gravimetrically as the difference between the weights of the filters before and after sampling, using a five-place analytical balance in a temperature-and-humidity controlled environment. The samples then were transferred into beakers containing small volumes of a surfactant solution (5% Triton X-100 in distilled water) and placed in an ultrasonic vibrator bath to dislodge particulate matter from the filter matrices. The resultant suspensions then were passed through 25-millimeter diameter polycarbonate membrane filters, 0.4 micrometer pore size, using vacuum filtration to achieve uniform sample deposits. After drying, the filters were placed on the rotating sample state of an X-ray diffractometer equipped with data control and data processor to provide both digital and graphic indication of detector responses. The masses of crystalline free silica (quartz, cristobalite, and tridymite) on the samples were determined by comparison of the relative responses, at the appropriate diffraction angles, of the scintillation detector to the copper $K\alpha$ -illuminated samples with the responses at the same angles to standards prepared by uniform deposition of known amounts of the pure materials on the same filter matrix.

Results of the gravimetric and X-ray diffraction analyses, which included any necessary corrections for blank determinations run in parallel with the analyses, were used to compute the "% SiO_2" (percent free silica) in each sample; the resultant figure then was used to compute the eight-hour, time-weighted average limit for exposure to the particulate matter collected in that sample. Results of the gravimetric analyses were used in conjunction with sampling data (measured flowrates and durations of sampling) to calculate concentrations of airborne particulate matter collected on the sampes, expressed in milligrams of particulate matter per cubic meter of air (mg/m3).

SULFUR DIOXIDE

Short-term instantaneous *sulfur* dioxide concentrations were determined utilizing a colorimetric indicator tube in conjunction with a hand-held bellows pump. The concentration of *sulfur dioxide* is read directly (in ppm) from the graduated tube indicated by a length of stain color change. This color change results as a reaction between sulfur dioxide, disodiumtetrachloromercurate, and methyl red to produce a change from yellow to orange.

TOTAL DUST

Samples to be analyzed for total dust were collected by drawing air at measured flowrates through cassetted polyvinyl filters, using battery-powered, portable pumps.

The mass of particulate matter collected on each filter was determined gravimetrically in the laboratory as the difference between the tare weight of the filter and the weight of the filter after sampling and equilibrium to balance room conditions.

Analytical results, which include any necessary corrections for blank determinations, were used in conjunction with the measured flowrates and sampling durations to calculate the concentrations of airborne analyte, expressed in unit of milligrams of analyte per cubic meter of air (mg/m3).

APPENDIX B

Summary of Sampling Results

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant Des Moines Power Station

Materials Total Dust & Crystalline Silica

Flow Rate 2.0 L.P.M.

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration		
			Start	Stop			T.D. mg/m^3	SiO_2 %	OSHA standard
2/4/81	FWS-B 19869	Plant Attendent Sam Allgeier	7:12 AM	2:13 PM	842	421	2.7	1.8	7.9
2/4/81	FWS-B 19877	Equipment operator - clean up Al Belinsky	7:32 AM	2:25 PM	826	413	1.0	2.8	6.2
2/4/81	FWS-B 19857	Equipment operator - clean up Bob Sowles	7:34 AM	2:26 PM	824	412	1.2	2.9	6.1
2/4/81	FWS-B 19864	Maintenance, Boilers 10 & 11 Ron Abel Levels 1, 2, 3	8:18 AM	3:33 PM	870	435	2.9	1.8	8.0
2/4/81	FWS-B 19874	Maintenance, Boilers 10 & 11 Ken Rice Levels 1, 2, 3	8:22 AM	3:40 PM	876	438	0.13	*	*

*Sample FWS-B 19874 contained insufficient dust deposit for a free silica analysis

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant Council Bluffs Power Station

Materials Total Dust & Crystalline Silica

Flow Rate 2.0 LPM

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration		
			Start	Stop			T.D. mg/m^3	SiO_2 %	OSHA standard
2/5/81	FWS-B 19867	Equipment operator - clean up Leland Percy	7:15 AM	2:38 PM	886	443	0.35	0.94	15
2/5/81	FWS-B 19860	Equipment operator - clean up Galen Gillette	7:16 AM	2:38 PM	884	442	0.40	0.69	15
2/5/81	FWS-B 19854	Coal handler - fly ash truck Ron Lee	7:38 AM	2:15 PM	794	397	6.9	1.6	8.2

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant Des Moines Power Station

Material Respirable Dust & Crystalline Silica

Date	Sample Number	Description	Sampling Period*		Total Sample Weight (mg)	Sample Volume (Liters)	Concentration			OSHA & ACGIH** Standard 10 mg/m^3 / % SiO_2+2
			Start	Stop			TRD (mg/m^3)	SiO_2 (mg/m^3)	SiO_2 (%)	
2/3/81	FWS-B 19856	Coal handler - tripper fl. Lester Dawson	7:46 AM	3:35 PM	0.53	797.3	0.67	.007	1.1	3.3
2/3/81	FWS-B 19861	Breaker House Rocco Vitiritto	7:53 AM	3:30 PM	0.56	776.9	0.72	.005	0.75	5.0

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant Des Moines Power Station

Material Respirable Dust & Crystalline Silica

Flow Rate 1.7 LPM

Date	Sample Number	Description	Sampling Period*		Total Sample Weight (mg)	Sample Volume (Liters)	Concentration			OSHA & ACGIH** Standard $\frac{10\ mg/m^3}{\%\ SiO_2+2}$
			Start	Stop			TRD (mg/m^3)	SiO_2 (mg/m^3)	SiO_2 (%)	
2/4/81	FWS-B 19859	Breaker House John Taylor	7:46 AM	3:34 PM	0.54	795.6	0.68	.009	1.3	3.1
2/4/81	FWS-B 19862	Foreman, Coal Gang Walt Casner	7:38 AM	2:51 PM	0.61	736.1	0.83	.017	2.0	2.5
2/4/81	FWS-B 19875	Coal Handler - Tripper Fl. Lester Dawson	7:41 AM	3:32 PM	0.64	800.7	0.80	.008	1.0	3.3

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant Council Bluffs Power Station

Material Respirable Dust & Crystalline Silica

Flow Rate 1.7 LPM

Date	Sample Number	Description	Sampling Period*		Total Sample Weight (mg)	Sample Volume (Liters)	Concentration			OSHA & ACGIH** Standard 10 mg/m3 / % SiO2+2
			Start	Stop			TRD (mg/m3)	SiO2 (mg/m3)	SiO2 (%)	
2/5/81	FWS-B 19873	Coal Handler - Tripper Fl. Mike Damgaard	7:40 AM	1:03 PM	0.38	549.1	0.69	.005	0.74	5.0
2/5/81	FWS-B 19865	Foreman Coal Gang Doug Feller	7:45 AM	2:07 PM	0.43	649.4	0.66	.002	<0.23	5.0
2/5/81	FWS-B 19871	Crusher House, Units 1 & 2 Steve Duff	7:51 AM	1:03 PM	0.39	530.4	0.74	.004	0.51	5.0

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant Council Bluffs Power Station

Material Respirable Dust & Crystalline Silica

Flow Rate 1.7 LPM

Date	Sample Number	Description	Sampling Period*		Total Sample Weight (mg)	Sample Volume (Liters)	Concentration			OSHA & ACGIH** Standard 10 mg/m^3 / % SiO_2+2
			Start	Stop			TRD (mg/m^3)	SiO_2 (mg/m^3)	SiO_2 (%)	
2/6/81	FWS-B 19868	Ash Pit - Unit one Don Cambell	8:18 AM	11:00 AM	0.15	275.4	0.55	*	*	*
2/6/81	FWS-B 19855	Crusher House Jamie Razor	7:34 AM	10:40 AM	0.41	316.2	1.3	.003	<0.25	5.0
2/6/81	FWS-B 19870	Tripper Floor Steve Duff	7:37 AM	10:40 AM	0.27	311.1	0.87	.003	<0.37	5.0
2/6/81	FWS-B 19866	Transfer House - Dumper Bld. #1,2,3,4 Ron Lee	7:40 AM	11:46 AM	0.50	418.2	1.2	.002	<0.20	5.0
2/6/81	FWS-B 19872	Fly Ash Truck Mike Damgaard	7:42 AM	2:10 PM	0.29	657.9	0.44	.002	<0.35	5.0
2/6/81	FWS-B 19876	Foreman, Coal Gang - Roving Doug Feller	7:46 AM	1:56 PM	0.25	629.0	0.40	.002	<0.40	5.0

*Sample FWS-B 19868 contained insufficient dust deposit for a free silica analysis

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant River Hills and Delaware Service Center

Materials Polychlorinated Biphenyls PCB

Flow Rate 1.0 LPM

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			PCB * mg/m^3	
2/2/81	FL-1	River Hills 1st Floor Near Feeder #46	7:58 AM	1:48 PM	350	350	<0.0003	
2/2/81	FL-2	River Hills 2nd Floor Hallway opposite fixed capaciter bank	8:07 AM	1:50 PM	343	343	<0.0003	
2/2/81	FL-3	River Hills - Basement Floor	8:14 AM	1:52 PM	338	338	<0.0003	
2/2/81	FL-4	Delaware Service Center Storage Area	8:45 AM	2:20 PM	335	335	<0.0003	

*Samples were quantitated using Aroclor 1262

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant Des Moines Power Plant

Removal of Pipe Lagging

Materials Airborne Asbestos

Flow Rate 2.0 LPM

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers/c.c.*	
2/4/81	AA-9	Dick Grandstaff	9:37 AM	10:22AM	90	45	1.3	
2/4/81	AA-10	Dick Grandstaff	10:22 AM	11:38AM	152	76	0.91	
2/4/81	AA-11	Michael Baker	9:34 AM	10:22 AM	84	42	0.56	
2/4/81	AA-12	Michael Baker	10:22 AM	11:38 AM	152	76	0.65	

*Fibers longer than 5 micrometers per c.c.

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant River Hills

Materials Airborne Asbestos

Flow Rate 2.0 LPM

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers/c.c.*	
2/2/81	AA-6	Near Feeder #46 1st Floor	7:58 AM	1:48 PM	700	350	<0.0011	
2/2/81	AA-7	Hallway opposite fixed capacitor banks - west side 2nd floor	8:07 AM	1:50 PM	686	343	<0.0011	
2/2/81	AA-8	Basement Floor	8:14 AM	1:52 PM	676	338	<0.0012	

*Fibers longer than 5 micrometers per c.c.

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant Walnut Street Office

Materials Airborne Asbestos

Flow Rate 1.7 LPM

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers/c.c.*	
2/2/81	AA-1	Personnel Office 1st Floor	8:20 AM	3:22 PM	717	422	0.0065	
2/2/81	AA-2	Ray Jenning's Office 2nd Floor	8:27 AM	3:22 PM	706	415	<0.0011	
2/2/81	AA-3	Keith Hosking's Office 3rd floor	8:35 AM	3:22 PM	692	407	0.0023	
2/2/81	AA-4	Engineering 4th Floor	8:47 AM	3:22 PM	672	395	0.0081	
2/2/81	AA-5	Return Air Plenum 6th Floor	9:00 AM	3:22 PM	649	382	<0.0012	
2/4/81	AA-13	Computer Room	7:41 AM	9:25 AM	177	104	<0.0037	
	AA-15	Blank						

*Fibers longer than 5 micrometers per c.c.

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant Print Shop Walnut Street
Des Moines, Iowa

Materials Acetone, Perchloroethylene and Petroleum Naphtha - Flow Rate 0.2 LPM

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration		
			Start	Stop			Acetone mg/m3	Prchlor. mg/m3	VM&P Naphtha mg/m3
2/3/81	Ct - 1	Charlie Patrick - Print Shop	9:25 AM	10:07 AM	8.4	42	0.51	13	2.8
2/3/81	Ct - 2	Charlie Patrick - Print Shop	10:08 AM	11:12 AM	12.8	64	<0.12	19	<0.58
2/3/81	Ct - 3	Blank	--	--			ND	ND	ND**

*Bulk sample of petroleum naphtha was not provided. Lab sample of VM&P naphtha was used to quantitate the concentrations of petroleum naptha. G.C. response was similar but not identical. Therefore results are reported as estimates.

**None detected

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant Council Bluffs Power Station

Materials Morpholine and Hydrazine

2/5/81

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Morpholine mg/m^3	Hydrazine mg/m^3
2/5/81	SG-2	Unit I Mix Tank	11:12 AM	3:01 PM	22.7	227	<0.11	
2/5/81	SG-3	Unit II Mix Tank	11:07 AM	3:02 PM	23.2	232	<0.10	
2/5/81	SG-4	Unit III Mix Tank	11:30 AM	3:10 PM	22.0	220	<0.11	
2/5/81	HYDZ-4	Unit I Mix Tank	11:13 AM	3:00 PM	227	227		<00.18
2/5/81	HYDZ-5	Unit II Mix Tank	11:06 AM	3:00 PM	234	234		<0.017
2/5/81	HYDZ-6	Unit III Mix Tank	11:30 AM	3:10 PM	220	220		<0.018

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant Des Moines Power Station

Materials Cyclohexalamine or Hydrazine

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Cyclohexalamine mg/m^3	Hydrazine mg/m^3
2/4/81	SG-1	Chemical Dispensing Area Power Station	9:21 AM	2:00 PM	27.9	279	<0.12	
2/4/81	HYDZ-7	Chemical Dispensing Area Power Station	9:52 AM	2:02 PM	250	250		<0.016
2/3/81	HYDZ-1	Chemical Dispensing Area Power Station	12:05 PM	4:08 PM	243	243		<0.016
2/3/81	HYDZ-2	Chemical Tank for #11 Boiler	1:54 PM	4:05 PM	191	191		<0.031
2/3/81	HUDZ-3	Chemical Tank for #10 Boiler	12:18 PM	3:59 PM	221	221		<0.018

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant Council Bluffs Power Station

Removal of Pipe Lagging

Materials Airborne Asbestos

Flow Rate 2.0 LPM

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers/cc*	
2/6/81	AA-14	Employee removing pipe insulation near maintenance shop	11:07 AM	11:27 PM	40	20	<0.019	

*Fibers longer than 5 micrometers per c.c.

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant Des Moines Power Station

2/4/81

Materials Sulfur Dioxide and Carbon Monoxide

Bendix/Gastec Detector System

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			SO_2	CO
2/4/81		East side, #11 Boiler Basement Level			0.2		3 PPM	--
2/4/81		Firing side, #11 Boiler Level 2			0.1		--	N.D.*
2/4/81		Firing side, #10 Boiler Level 2			0.1		--	N.D.
2/4/81		Steam Drum, #10 Boiler South End			0.1		--	N.D.
2/4/81		Steam Drum #11 Boiler East End			0.1		--	N.D.
2/4/81		East side, #11 Boiler Level 7, outside			0.2		2 PPM	--

*N.D. - None Detected

NOISE EXPOSURE DATA SHEET

Company Council Bluffs Power Station Date 2/5/81 Test by David DeRoos & Ken Smith

Readout Model No. R-225 S/N 901507

Operating Conditions Calibrator Model No. C-114 S/N 09011446

Unit No.	Cell No.	Employee Name / Job Description	Exposure Period: Stop/Start	Exposure Period: Total Time (hrs.)	Percent of 90 dBA: Indicated	Percent of 90 dBA: Adjusted to 8 hrs.	Equivalent 8-hour Exposure (dBA)	115 dBA Exceeded (X)
9812	6936	Lelan Percy Equipment operator - clean up	2:38 PM 7:15 AM	6.9	64	74.2	88	X
9298	6938	Galen Gillette Equip. Operator - clean up	2:38 PM 7:16 AM	6.9	66	76.5	88	X
9414	6939	Ron Lee Coal Handler - Fly Ash Truck	2:15 PM 7:36 AM	6.2	02	2.6	63	
9808	6937	Doug Feller - Coal Handler Foreman - Roving	2:08 PM 7:40 AM	7.0	04	4.6	68	
7944	4429	Steve Duff - Coal Handler Crusher House, Units 1&2	1:07 PM 7:46 AM	5.9	43	58	86	

NOISE EXPOSURE DATA SHEET

Company Des Moines Power Station Date 2/3/81 Test by R. Fortney & K. Smith

Readout Model No. R-225 S/N 901507

Operating Conditions Units 6 & 7 Calibrator Model No. C-114 S/N 09011446

Unit No.	Cell No.	Employee Name / Job Description	Exposure Period: Stop/ Start	Exposure Period: Total Time (hrs.)	Percent of 90 dBA: Indicated	Percent of 90 dBA: Adjusted to 8 hrs.	Equivalent 8-hour Exposure (dBA)	115 dBA Exceeded (X)
9806	6940	Lester Dawson Coal Handler - Tripper Floor	3:33 PM 7:46 AM	7.3	47	51.5	85.0	
9298	6939	Rocco Vitiritto Breaker House	3:32 PM 7:53 AM	7.2	14	15.6	76.6	
9414	6937	John Taylor Cat Operator	3:38 PM 8:00 AM	7.1	01	1.13	57.6	
9812	6938	Ron Abel Maintenance	3:31 PM 8:13 AM	6.8	52	61.1	86.5	
9808	6936	Ken Rice Maintenance	3:35 PM 8:21 AM	6.7	95	113	90.9	

NOISE EXPOSURE DATA SHEET

Company Des Moines Power Station Date 2/4/81 Test by R. Fortney & K. Smith

Readout Model No. R-225 S/N 901507

Operating Conditions _____ Calibrator Model No. C-114 S/N 09011446

Unit No.	Cell No.	Employee Name / Job Description	Exposure Period: Stop/Start	Exposure Period: Total Time (hrs.)	Percent of 90 dBA: Indicated	Percent of 90 dBA: Adjusted to 8 hrs.	Equivalent 8-hour Exposure (dBA)	115 dBA Exceeded (X)
9812	6938	Mike Moritz Equipment Operator	2:23 PM 6:52 AM	7.0	121	138	92.5	X
9298	6939	Brian Demsky Equipment Operator	2:24 PM 6:54 AM	7.0	72	82	88.5	
9806	6940	Otis Wiand Clean up operator	2:29 PM 6:57 AM	7.0	30	34	82.2	
9414	6937	Bob Sowles Equipment Operator - clean up	2:27 PM 7:14 AM	6.7	08	9.5	73.0	
9808	6936	Al Belinsky Equipment Operator - clean up	2:25 PM 7:13 AM	6.7	30	35.8	82.9	

Bulk Sample Analysis

		Asbestos
1.	Dust Insulation, 6th floor office Walnut Street	25% chrysotile asbestos
2.	Structural Insulation, 4th floor Walnut Street	5% cellulose fibers no asbestos detected
3.	Ceiling tile, 3rd floor office Walnut Street	10% chrysotile asbestos 70% mineral wool
4.	Ceiling tile, 1st floor office Walnut Street	80% mineral wool no asbetos detected
5.	Sprayed-on ceiling, 1st floor Assembly Hall, Walnut Street	15% chrysotile asbestos
6.	Pipe Insulation, DPS	15% chrysotile asbestos 55% amosite asbestos
7.	Pipe Insualtion, CBPS	30% chrysotile asbestos 35% amosite asbestos

NOISE EXPOSURE DATA SHEET

Company Des Moines Power Station Date 2/4/81 Test by R. Fortney & K. Smith

Readout Model No. R-225 S/N 901507

Operating Conditions Units 6 & 7 Calibrator Model No. C-114 S/N 0901146

Unit No.	Cell No.	Employee Name / Job Description	Exposure Period: Stop/ Start	Exposure Period: Total Time (hrs.)	Percent of 90 dBA: Indicated	Percent of 90 dBA: Adjusted to 8 hrs.	Equivalent 8-hour Exposure (dBA)	115 dBA Exceeded (X)
7770	4805	Lester Dawson Coal Handler - Tripper Floor	3:30 PM 7:39 AM	6.4	37	46	84.4	
7635	4804	John Taylor Coal Handler - Breaker House	3:32 PM 7:44 AM	6.3	38	48	84.7	
7676	4801	Walt Casner Coal Handler - Breaker House	3:15 PM 7:50 AM	6.9	14	16	76.8	
7944	4802	John Haluska Welding - Pipe Fitting	3:24 PM 8:09 AM	6.8	117	138	92.3	X

Wipe Sample Analysis

	PCB's gm//filter*
1. Side of Feeder #46 1st floor, River Hills	1.8
2. Side of Feeder #44 1st floor, River Hills	<0.50

* gm/filter - micrograms of PCB/Whatman filter

APPENDIX C

Current Regulations

APPLICABLE OCCUPATIONAL HEALTH STANDARDS FOR AIR CONTAMINANTS

Substances	Units	American Conference of Governmental Hygienists (ACGIH) (1979)			Occupational Safey & Health Administration (OSHA)		National Institute for Occupational Safety and Health (NIOSH) Proposed	
		8-hr[1]	Stel[2]	Ceiling[3]	8-hr[1]	Ceiling[4]	10-hr[1]	Ceiling[5]
Arsenic	mg/m^3	0.5	--	--	0.01	--	--	0.002 (15 min)
Asbestos	fibers/cc	2	--	--	2	10	0.1*	0.5 (15 min)
Carbon Monoxide	ppm	50	400	--	50	--	35	200
Hydrazine (skin)	mg/m^3	0.1	--	--	1.3	--	--	0.04 (120 min)
Morphaline (skin)	mg/m^3	70	105	--	70	--	--	--
Noise	dB(A)	85	--	115	90	115	85*	115
Sulfur Dioxide	ppm	2	5	--	5	--	0.5	--
Total Nuisance Dust	mg/m^3	10	20	--	15	--	--	--
Total Respirable Dust	mg/m^3	5	--	--	5*	--	--	--
Total Respirable Coal Dust	mg/m^3	2	--	--	2.4*	--	--	--
Total Coad Dust	mg/m^3	4	--	--	--	--	--	--

[1] 8-hr or 10-hr - The time weighted average for an 8- or 10-hour work shift in a 40-hour workweek
[2] Stel - ACGIH's standard maximum concentration which workers can be exposed up to 15 minutes
[3] Ceiling (ACGIH) - The concentration that should not be exceeded even instantaneously
[4] Ceiling (OSHA) - The concentration that should not be exceeded even instantaneously, except when the standard has a peak value (explanations will be given for chemicals with peak values)
[5] Ceiling (NIOSH) - The average maximum concentration which cannot be exceeded for a short period

APPENDIX D

Toxicological Effects

ACETONE

Acetone ($(CH_3)2$ CO) is a clear, colorless, flammable liquid, with a burning taste and a characteristic sweetish odor. However, it is a highly flammable and explosive substance.

Acetone is very volatile and may be inhaled in large quantities when it is present in high concentrations. It may be absorbed into the blood through the lungs and diffused throughout the body. Small quantities may be absorbed through the skin. Typical symptoms, following acetone exposure are narcosis, slight skin irritation and more pronounced mucous membrane irritation. Exposure to high concentrations produces a feeling of stupor and delayed breathing and finally, coma. In some cases, albumin and red and white blood cells in the urine indicate the possibility of kidney damage and in others, liver damage can be presumed. The longer the exposure, the lower the respiratory rate and pulse; these changes are roughly proportionate to the acetone concentration. Cases of chronic poisoning resulting from prolonged exposure to low concentrations of acetone are rare; however, in cases of repeated exposure to low concentrations, complaints were received of headache, drowsiness, vertigo, irritation of the throat and coughing.

At a concentration of 300 ppm acetone produces irritation of mucous membranes which is generally tolerable up to 500 ppm. At 1000 ppm, a slight narcotic effect is also observable. In one study, workers with seven to fifteen years exposure, three hours per day to 1000 ppm complained of chronic inflammation of the respiratory tract, stomach and duodenum and, in some cases, of dizziness and asthenia.

Being considered one of the least toxic of the common solvents, the Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) both have established an eight-hour, time-weighted average (TWA) concentration limit of 1000 ppm as a standard for occupational exposure. ACGIH has recommended a shortterm exposure limit (up to 15 minutes) of 1250 ppm.

ASBESTOS

Asbestos is a generic term referring to various fibrous mineral silicates, including chrysotile (hydrated magnesium silicate), amosite (iron-magnesium silicate), crocidolite (sodium-iron silicate), tremolite (calcium-magnesium silicate), anthophyllite (another iron-magnesium silicate), and actinolite (calcium-magnesium-iron silicate).

The potential health hazard associated with exposure to asbestos results from inhalation of airborne fibers; small asbestos fibers can pass readily through the upper respiratory tract and be deposited in the terminal bronchioles of the lung. There they can produce a local irritation which the body attempts to overcome by initiating a tissue response resulting in the encapsulation of the fibers and consequent formation of "asbestos bodies". Asbestos fibers are the causative agents in cases of asbestosis, a progressive disease characterized by diffuse interstitial fibrosis and, at times, pleural changes of fibrosis and calcification. It is often evident by such clinical signs as rales and dyspnea. In its severe form, asbestosis can contribute to, and result in, death due to the inability of the body to obtain oxygen or the heart to pump blood through the scarred lungs.

Exposure to airborne asbestos fiber also has been associated with bronchogenic carcinoma (a malignancy of the interior of the lung), mesothylioma (a diffuse malignancy of the lining of the chest or abdomen), and cancer of the stomach, colon, and rectum. Cigarette smoking can enhance the incidence of bronchogenic carcinoma from this substance.

In order to protect workers from such occupational hazards, the Occupational Safety and Health Administration (OSHA) has established a limit of two fibers (longer than five micrometers) per cubic centimeter of air as an eight-hour, time-weighted average concentration limit. This OSHA standard also specifies a ceiling (peak) exposure limit of ten fibers per cubic centimeter of air. The American Conference of Governmental Industrial Hygienists (ACGIH) has established a threshold limit value of five fibers (longer than five micrometers) per cubic centimeter of air. The National Institute for Occupational Safety and Health (NIOSH) has recommended a daily time-weighted average exposure limit of 0.1 fiber per cubic centimeter of air, with a peak concentration limit of 0.5 fibers per cubic centimeter based on a 15 minute sample period.

CARBON MONOXIDE

Carbon monoxide (CO) is a colorless, odorless gas generally produced by incomplete combustion of organic or carbonaceous materials. It is a serious hazard in many processes in the chemical, iron and steel, pottery, automobile, and mining industries.

Of all the gases that have poisonous effects upon man and animals, carbon monoxide is the most widely encountered. It exerts its effects by combining with the hemoglobin of the blood and interrupting the normal oxygen supply to the body tissues. Although this resultant oxygen deficiency is a reversible chemical asphyxia, nevertheless, damage done by severe asphyxia from any cause may not be reversible.

The acute effects of carbon monoxide exposures are dependent on the percentage saturation of hemoglobin with carbon monoxide, which in turn is dependent on the duration of exposure, concentration of carbon monoxide, the ambient temperature, and the health status and metabolic efficiency of the worker. The approximate relationship is shown in the following table.

Atmospheric Carbon monoxide concentration (ppm)	Half-time for accumulation (min)	Carboxy-hemoglobin concentration at equilibrium %	Principal Symptoms
50	150	7	Slight headache
100	120	12	Moderate headache and dizziness
250	120	25	Severe headache and dizziness
500	90	45	Nausea, vomiting collapse possible
1,000	60	60	Coma
10,000	5	95	Death

The Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) have established a permissible exposure limit (PEL) for an eight-hour, time-weighted average, (TWA) exposure of 50 ppm to maintain carboxyhemoglobin levels below 10%. The National Institute for Occupational Safety and Health recommends a time-weighted average exposure of 35 ppm for an eight-hour workday, with a ceiling concentration of 200 ppm. ACGIH currently lists as "tentative value" a short-term exposure limit (up to 15 minutes) of 400 ppm.

COAL DUST

Coal is a native, black or brownish, brittle or soft substance consisting chiefly of carbon, but also of hydrogen, nitrogen, oxygen and other elements (Si, P, AS, Fe, etc.).

A commonly used term for chest disease resulting from inhalation of coal is coal workers' pneumoconiosis. Another frequently used term is anthrosilicosis, an appropriate description, since all coals contain not only carbon, but varying amounts of silica.

In chronic respiratory disease of coal workers, the onset is gradual, often forcing the patient to seek medical advice for the first time only after a bacterial infection or heavy exposure to dust in a mine accident. Cough, wheezing, severe dyspnea, and sputum production varies with infection and smoking habits. The sputum is usually black, and in advanced disease large amounts of thick material referred to as melanosis are produced indicating cavities caused by aseptic necrosis. Tuberculosis and bacterial pneumonia, although more manageable with modern chemotherapy, are serious complications. Pulmonary arterial circulation involvement and right heart failure are secondary to emphysema and hypoxia leading to increasing disability and death.

The Occupational Safety and Health Administration (OSHA) has established an eight-hour, time-weighted average (TWA) concentration limit of 2.4 mg/m3 for "respirable" coal dust containing less than five percent quartz, and established the following formula as an eight-hour, TWA concentration limit for respirable coal dust containing more than five percent quartz:

$$TLV = \frac{10\ mg/m3}{\%\ SiO_2 + 2}$$

The American Conference of Governmental Industrial Hygienists (ACGIH) has adopted an eight-hour, TWA threshold limit value of 2 mg/m3 for respirable coal dust containing less than five percent quartz. If the coal dust contains more than five percent quartz, ACGIH also recommends the respirable mass formula established by OSHA. The National Institute for Occupational Safety and Health (NIOSH) has recommended a TWA concentration limit of 0.05 mg/m3 of free silica in respirable dusts.

CYCLOHEXYLAMINE

Cyclohexylamine ($C_6H_{11}NH_2$) is a colorless liquid of a strong base, with unpleasant odor. It can enter the human body via inhalation of vapor and percutaneous absorption of liquid.

It presents severe caustic actions on skin and mucous membranes. It also causes systemic effects in humans including nausea and vomiting, anxiety, restlessness, and drowsiness. Cyclohexylamine is regarded as having moderate sensitizing potential and being a weak methemoglobin-forming substance.

Some recent reports of animal experiments have indicated that cyclohexylamine might have potential carcinogenic, mutagenic or teratogenic activity. An adverse effect of oral cyclohexylamine sulfate on fertility in male rats was detected.

No chronic experimental toxicity studies on cyclohexylamine have been reported. Exposure to 4-10 ppm caused no symptoms of any kind in workmen under acute conditions.

In view of the pronounced toxic and irritant effects of cyclohexylamine and the possibility that continued absorption might lead to carcinogenic, mutagenic or teratological effects, the American Conference of Governmental Industrial Hygienists (ACGIH) has adopted an eight-hour, time-weighted average (TWA) threshold limit value (TLV) of ten parts of cyclohexylamine per million parts of air by volume. The TLV carries the "skin" notation, warning of the potential for percutaneous absorption; the TLV is based on the presumption that there is no concurrent exposure via the skin absorption and oral ingestion routes.

HYDRAZINE AND ITS DERIVATIVES

Hydrazine (NH_2-NH_2) is a colorless, oily liquid with an ammoniacal odor. Phenyl-hydrazine (C_6H_5NH-NH_2) is an oily colorless, liquid or a crystalline solid. 1,1-Dimethylhydrazine ($(CH_3)_2$-N-NH_2) is a hydroscopic mobile liquid. The potential for worker exposure to the hydrazines is primarily through two routes of exposure, inhalation and contact with skin or eyes.

Hydrazine and its derivatives are believed to pose a carcinogenic risk to humans since a wide variety of studies have shown that exposed rodents have developed an elevated incidence of lung tumors. Liver damage is the most serious effect, other than cancer, of hydrazine toxicity.

All three compounds have similar toxic local effects due to their irritant properties. The vapor is highly irritating to the eyes, upper respiratory tract, and skin, and causes delayed eye irritation. Severe exposure may produce temporary blindness. The liquid is corrosive, producing penetrating burns and severe dermatitis. Permanent corneal lesions may occur if the liquid is splashed in the eyes. A sensitization dermatitis may be produced.

Currently accepted exposure limits established or recommended by the Occupational Safety and Health Administration (OSHA), the American Conference of Governmental Industrial Hygienists (ACGIH) and the National Institute for Occupational Safety and Health (NIOSH) are as follows:

Chemical	Unit	OSHA	ACGIH		NIOSH
		TWA*	TWA*	STEL**	CEILING***
Hydrazine	ppm	1	0.1	-	0.03
Methylhydrazine	ppm	-	-	-	0.04
1,1-Dimethylhydrazine	ppm	0.5	0.5	1	0.06
Phenylhydrazine	ppm	5	5	10	0.14

*TWA - The time-weighted average for an eight-hour work shift in a 40-hour work week.

**STEL - (Short-term exposure limit) - The maximal concentration to which workers can be exposed for a period up to 15 minutes.

***CEILING - The maximum concentration which cannot be exceeded in any two-hour period.

All the exposure limits carry the "skin" notation, warning of the potential for percutaneous absorption; these specific concentration limits are based on the presumption that there is no concurrent exposure via the skin and oral ingestion routes.

MERCURY
(ALL FORMS EXCEPT ALKYL)

Mercury (Hg) is here taken to include elemental mercury, inorganic mercury compounds, and organic mercury compounds, excluding alkyl mercury compounds. Metallic mercury is a silver-white liquid at room temperature. Mercury can enter the human body via inhalation of dust or vapor and percutaneous absorption of elemental mercury. Metallic mercury readily vaporizes at room temperature and the vapor has no warning properties.

Acute exposure to mercury at high airborne concentrations causes severe respiratory irritation, digestive disturbances, and marked renal damage, usually of delayed onset. Exposure to lower levels over prolonged periods produces chronic mercurialism which is characterized by neurologic and psychic disturbances, anorexia, weight Exposure of humans to mercury vapor in concentrations of 1.2 to 8.5 mg/m3 causes cough, chest pain, and dyspnea, leading to bronchitis and pneumonitis. The onset of symptoms resulting from chronic exposure is insidious. Fine tremor of the hands, eyelids, lips and tongue are often the presenting complaints. Coarse jerky movements and incoordination may interfere with the fine movements required for writing and eating. Phychic disturbances such as insomnia, irritability and indecision occur; headache, excessive fatigue, anorexia, digestive disturbances, and weight loss are common.

Stomatitis with excessive salivation is sometimes severe. Mercury has a cumulative effect and has a tendency to deposit in certain organs, most notably the brain, liver and kidneys, although it can be found in nearly all tissues. Mercury is a primary irritant of skin and mucous membranes. It may occasionally be a skin sensitizer.

The Occupational Safety and Health Administration (OSHA) has established a ceiling concentration limit of 0.1 mg/m3 as a standard for occupational exposure to mercury. The American Conference of Governmental Industrial Hygienists (ACGIH) and the National Institute for Occupational Safety and Health (NIOSH) both have recommended an eight-hour, time-weighted average (TWA) concentration limit of 0.5 mg/m3 (as Hg) for occupational exposure to all forms of mercury except alkyl. ACGIH currently lists as "tentative" a short-term exposure limit (up to 15 minutes) of 0.15 mg/m3.

MORPHOLINE

Morpholine (C_4H_8ONH) is a colorless, hygroscopic liquid with amine-like odor. It can enter the human body via inhalation of vapor or percutaneous absorption of liquid.

Morpholine vapor is an irritant of the mucous membranes. Symptoms include visual aberrations, noise irritation, cough, respiratory irritation, severe eye and skin irritation from liquid splashes, skin irritation from repeated or prolonged overexposure.

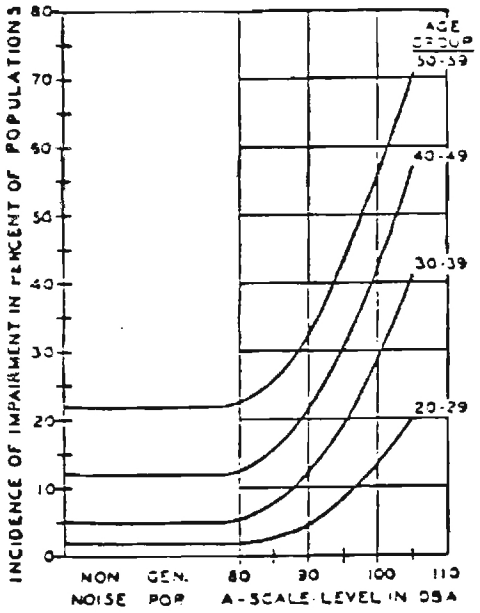
Some instances of skin and respiratory tract irritation have been observed in industry. Workers exposed to low vapor concentrations for several hours complained of foggy vision with rings around lights, the result of corneal edema which cleared within three to four hours after cessation of exposure. The liquid is a severe skin irritant. The liquid dropped in the eye of a rabbit caused moderate injury, with ulceration of the conjunctiva and corneal clouding.

The effects on animals from exposure to morpholine have been described as similar to those produced by ammonium hydroxide. Nasal and bronchial irritation, as with ammonia gas, and liver damage predominate.

To prevent irritation and harmful effects on the eyes and vision, the Occupational Safety and Health Administration (OHSA) and the American Conference of Governmental Industrial Hygienists (ACGIH) both have established an eight-hour, time-weighted average (TWA) concentration limit of 20 ppm as a standard for occupational exposure. ACGIH also lists as "tentative" a short-term exposure limit (up to 15 minutes) of 30 ppm. This standard carries the "skin" notation, warning of the potential for percutaneous absorption; the specific concentration limit is based on the presumption that there is no concurrent exposure via the skin absorption and oral ingestion routes.

NOISE

The major potential health hazard associated with exposure to noise lies in the possibility of producing permanent hearing loss. Factors which plan a role in deciding how much permanent hearing loss will be sustained after exposure to high noise levels include the level and frequency of the noise, the duration of exposure per day, the number of years of repeated daily exposure, and individual susceptibility (age, genetic make-up, diet, and use of autotoxic drugs are just some of the variables which determine individual susceptibility). One rough estimate of the percentage of the exposed population which will develop hearing impairment after working continuously at different noise levels is presented in the figure below.



PREVALENCE OF IMPAIRED HEARING AND SOUND LEVELS AT WORK

The other adverse effects suspected as being caused by high noise levels include physiological disturbances (high bloodpressure, aural pain, nausea and impaired muscular control when exposure is severe), and an increase in the accident frequency rate resulting from interference with speech communication and the disrupting of concentration. Also, some temporary hearing loss results from daily exposure to high noise levels, reportedly because the hair cells in the inner ear become fatigued and can no longer respond as well.

NUISANCE DUST

In contrast to fibrogenic dusts which cause scar tissue to be formed in lungs when inhaled in excessive amounts, so-called "nuisance" dusts have a long history of little adverse effect on lungs and do not produce significant organic disease or toxic effect when exposures are kept under reasonable control. The nuisance dusts have also been called (biologically) "inert" dusts, but the latter term is inappropriate to the extent that there is no dust which does not evoke some cellular response in the lung when inhaled in sufficient amounts. However, the lung-tissue reaction caused by inhalation of nuisance dusts have the following characteristics:

(1) The architecture of the air spaces remains intact.

(2) Collagen (scar tissue) is not formed to a significant extent.

(3) The tissue reaction is potentially reversible.

Excessive concentrations of nuisance dusts in the workroom air may seriously reduce visibility, may cause unpleasant deposits in the eyes, ears and nasal passages or cause injury to the skin or mucous membranes by chemical or mechanical action per se or by rigorous skin cleansing procedures necessary for their removal. They do not appear to have a predisposing effect on tuberculosis or other infection and do not cause impaired lung function.

The American Conference of Governmental Industrial Hygienists (ACGIH) has established time-weighted average (TWA) threshold limit values of 30 mppcf (millions of particles per cubic foot of air), based on impinger samples counted by light-field techniques or 10 mg/m3 of total dust containing less than 1% quartz, or 5 mg/m3 respirable dust. The Occupational Safety and Health Administration (OSHA) has established TWA standards of 50 mppcf or 15 mg/m3 for total dust containing less than 1% quartz, or 15 mppcf or 5 mg/m3 for respirable dust.

Quite often an industrial hygienist will use a gravimetric analysis for total dust when sampling for dusts with unknown toxicity. While the results may be compared to the nuisance dust standard for a base line reading, the dusts of unknown toxicity should in no way be considered nuisance dusts because the potential for harm has not been established.

PERCHLOROETHYLENE

Perchloroethylene (1,1,2,2-tetrachloroethylene) is a colorless solvent with an odor like ether or chloroform. Human exposure to high concentrations of the vapor in air may result in maladies of the liver, kidneys, eyes, upper respiratory system, and the central nervous system. Skin contact with liquid perchloroethylene may result in skin burns, blistering, erythema. Skin effects due to chronic perchloroethylene exposure (in air) may result in eczema.

Symptoms of exposure to perchloroethylene vapors vary depending on the concentration. At relatively low concentrations (75-100 ppm) one may experience lightheadedness, slight eye irritation, throat irritation, and frontal headache. At higher concentrations symptoms of fatigue, vertigo, nausea, and vomiting may become apparent. Prolonged exposure to high concentrations may lead to liver dysfunction, pulmonary edema, kidney failure, neurological disorders, coma, and eventually death.

The current Occupational Safety and Health Administration Permissible Exposure Limit for perchloroethylene is 100 ppm based on an 8-hour, time-weighted average (TWA). The National Institute for Occupational Safety and Health recommended standard is 50 ppm based on a 10-hour, TWA.

POLYCHLORINATED BIPHENYLS (PCB'S)

PCB's ($C_{12}H_{10-x}Cl_x$ chlorodiphenyls) are diphenyl rings in which one or more hydrogen atoms are replaced by chlorine atoms. Most widely used are trichlorophenyl (42% chlorine) containing three chlorine atoms in unassigned positions and pentachlorophenyl (54% chlorine) containing five chlorine atoms in unassigned positions. These compounds are light, straw-colored liquids with typical chlorinated aromatic odors; 42% chlorodiphenyl is a mobile liquid and 54% chlorodiphenyl is a viscous liquid. In industry, PCB"s can enter the human body mainly via inhalation of fume or vapor and percutaneous absorption of liquid.

The major effects that have been found in workers exposed to PCB's are chloracne, liver injury, and irritation of skin and mucous membranes. Generally, the toxic effects are dependent upon the degree of chlorination; the higher the degree of substitution, the stronger the effects.

In humans, systemic effects are anorexia, nausea, edema of the face and hands, and abdominal pain. In a survey of 34 workers exposed to concentrations of up to 2.2 mg/m3, complaints were of a burning sensation of the face and hands, nausea, and a persistent (uncharacterized) body odor. Cases of mild-to-moderate skin irritation with an acneform eruption have been reported in workers exposed to 0.1 mg/m3. Several deaths from toxic hepatitis occurred among workers exposed to the fumes of PCB's and chloronaphthalenes.

PCB's are poorly metabolized and tend to accumulate in animal tissues, including humans. Currently, a possible link between PCB"s exposure and cancer has been reported.

To protect against systemic intoxication, the Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) both have established eight-hour, time-weighted average concentration limits of 1 mg/m3 for chlorodiphenyl (42% chlorine) and 0.5 mg/m3 for chlorodiphenyl (54% chlorine). ACGIH currently lists as "tentative" short-term exposure limits (up to 15 minutes) of 2 mg/m3 and 1 mg/m3 for the two substances, respectively.

Based on the findings of adverse reproductive effects, on its conclusion that PCB's are potential carcinogens in humans and on its conclusion that occupational and animal studies have not demonstrated an exposure level that will not subject the workers to possible liver injury, the National Institute for Occupational Safety and Health (NIOSH) recommends a TWA concentration limit of 1 microgram total PCB's per cubic meter of air (1 µg/m3) for up to a 10-hour workday, 40-hour workload. The standards established by OSHA and ACGIH carry the "skin' notation, warning of the potential for percutaneous absorption; the specific concentration limits are based on the presumption that there is no concurrent exposure via the skin and oral ingestion routes.

The Environmental Protection Agency (EPA) has taken action under Toxic Substances Control Act (TSCA) aimed at controlling the production, distribution, use, and disposal of PCB's.

SILICEOUS DUSTS

Free silica (SiO_2, uncombined and independent of other elements) has three crystalline forms: quartz, tridymite, and cristobalite. All three forms have similar physiologic action. The potential health hazard associated with exposure to crystalline silica is that of inhalation of the dust. Inhalation of extreme concentrations of submicron particles can lead to diffuse, fulminating lung fibrosis within a few months. However, development of the more common chronic type of silicosis usually takes many years. The effects of repeated inhalation of siliceous dusts are cumulative and progressive. The chronic disease is characterized by an initial generalized linear increase in lung density progressing to small nodules scattered throughout the lung tissue. If exposure continues, these nodules increase in size to the point where they interfere with respiration. Although silicosis rarely causes death, common complications include tuberculosis, chronic bronchitis and bacterial infections.

The Occupational Safety and Health Administration (OSHA) has established the following formula as an eight-hour, time-weighted average (TWA) concentration limit, based on the quartz content of total dust:

$$TLV = \frac{30\ mg/m3}{\%\ SiO_2+2}$$

The American Conference of Governmental Industrial Hygienists (ACGIH) has adopted a TWA threshold limit value (TLV) formula based on the free crystalline quartz content for total dust:

$$TLV = \frac{30\ mg/m3}{\%\ SiO_2+3}$$

OSHA and ACGIH both have established a formula applicable to calculate acceptable air concentrations of the respirable fraction of total dust:

$$TLV = \frac{10\ mg/m3}{\%\ SiO_2+2}$$

If the free crystalline silica content is composed primarily of tridymite and/or cristobalite, one-half the value calculated from the formula for quartz must be used.

The National Institute for Occupational Safety and Health (NIOSH) has recommended a TWA concentration limit of 0.05 mg/m3 of free silica in respirable dust.

SULFUR DIOXIDE

Sulfur dioxide (SO_2) is a pungent, irritating, and colorless gas having an odor characterized and recognized as a "burning sulfur". It has an odor threshold of approximately three ppm.

Sulfur dioxide is intensely irritating to the eyes, throat, and upper respiratory system. Effects are primarily irritation of mucous membranes.

It is most likely absorbed as sulfurous acid, which is formed rapidly when sulfur dioxide contacts moist mucous membranes of man. The ultimate fate of practically all absorbed sulfur dioxide is apparently oxidation to sulfate ion, to be excreted principally as the inorganic sulfate ion in the urine.

Sulfur dioxide concentrations above 20 ppm have a marked irritant, choking, and sneeze-producing effect. Acute exposure to concentrations of about 50 ppm will promptly cause irritation of the nose and throat, rhinorrhea, and cough. A concentration of 150 ppm is so extremely irritating that it can be endured only for a few minutes. Asphyxia or severe chemical bronchopheumonia may result from accidental exposures to extremely high concentrations.

Sulfur dioxide gas is irritating to the eyes, producing burning discomfort and lacrimation. Liquid sulfur dioxide from pressurized containers can produce severe burns to the cornea of the eye which may be deceptively painless for the first few hours or even days. Over the course of weeks or months after such contact, the cornea may become infiltered and densely vascularized resulting in opacification and severe loss of vision.

Sulfur dioxide interaction with aerosols has currently received considerable attention. Interaction with stack dust aerosol produced potentiated (i.e., enhanced, stronger) activity. Soluble salts of manganese, ferrous iron, and vanadium also produced potentiated sulfur dioxide-aerosol activity. The metal ions are known to promote the catalytic conversion of sulfur dioxide to sulfuric acid.

Some individuals appear to overreact to concentrations of sulfur dioxide which, in most persons, elicit much milder responses. This hypersusceptibility may occur in 10 to 20% of healthy, young adults.

To prevent respiratory tract irritation in most workers, the Occupational Safety and Health Administration and the American Conference of Governmental Industrial Hygienists both have established a limit for occupational exposure to sulfur dioxide of 5 ppm, expressed as an eight-hour, time-weighted average concentration. The National Institute for Occupational Safety and Health recommends a standard of 2 ppm as an eight-hour, time-weighted average concentration limit.

APPENDIX E

Industrial Hygiene Reference Material

Publications

1) NIOSH/OSHA, Pocket Guide to Chemical Hazards
DHEW (NIOSH) Publication #78-21

2) Occupational Diseases - A Guide to Their Recognition
DHEW (NIOSH) Publication #77-181

3) NIOSH Manual of Sampling Data Sheets
DHEW (NIOSH) Publication #77-159

4) NIOSH Occupational Exposure Sampling Strategy Manual
DHEW (NIOSH) Publication #77-173

5) Recommended Industrial Ventilation Guidelines
DHEW (NIOSH) Publication #76-162

All of the above publications are available at nominal cost from NIOSH. Single copies are generally available free upon formal request to the Regional Industrial Hygienist for NIOSH at their nearest regional office.